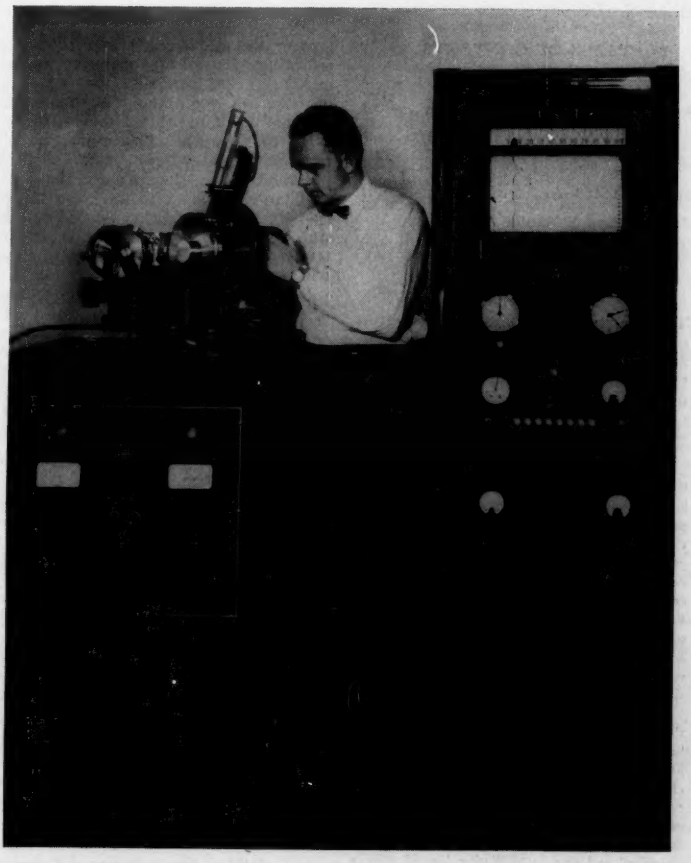
STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

MARCH ATLANTA, GEORGIA 1952



The Research Engineer

Published in May, September, November, January, and March by the State Engineering Experiment Station of the Georgia Institute of Technology, Atlanta, Georgia, 1951-1952 Volume, No. 5. Entered as second-class matter September 20, 1948, at the post office at Atlanta, Georgia, under the Act of August 24, 1912. Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, Section 538, P.L.&R., authorized October 18, 1948.

GERALD A. ROSSELOT, *Director* FRED W. COX, JR., *Assistant Director*

JOHN C. LANE, *Editor*

PAUL WEBER, *Associate Editor*

ROBERT J. KYLE, *Assistant Editor* NANCY D. WASTLER, *Assistant*

TABLE OF CONTENTS

X-Rays at Work for Industry 3

Raw Materials from Plants 5

Electrification in Aerosol Studies 7

Photographic Job Study 9

Index to 1951-52 Issues 11

Cover: Electron Diffraction Apparatus.

APPRECIATION OF RESEARCH

Two recent publications, both concerned with developing a stronger technology in Free Europe, point up the need of some segments of our own industry for a better understanding and greater use of research and the contributing sciences. One publication discusses the Continent's almost total lack of chemical engineering education as we know it. The other attempts to explain to Europeans how we go about translating laboratory research into practical usage—the process that, by and large, we seem to have developed further than any other nation. Both publications advocate sharing these potent accelerators of industrial progress with our foreign friends.

Surely there can be no doubt that our efforts to develop chemical engineering in Europe would, in time, be rewarded by an increased flow to Amer-

Continued on Page 24

Higher salaries have been advanced as one partial solution to the present shortage of engineers. Salary levels more commensurate with their importance in our technologically advanced civilization are undeniably the due of engineers as a professional group. However, the individual engineer will always find, whether general levels rise or not, that his pay is largely determined by what he is worth to his company. When men of equal ability are scarce, he can demand more. But over the long term, his greatest hope for a superior salary is demonstration of superior ability.

Our leading technological schools have built their reputations on giving their graduates the best possible academic background. Many companies have orientation and training programs to close the gap between college and industry. Some even have a special group to watch the young man's progress and bring him along as rapidly as his growth permits. Thus, judicious choice of his school and care in affiliating himself with a progressive company are two things important to the ambitious engineer.

However, much of the responsibility for his development lies with the man himself. His application while in school, his decision regarding graduate studies, his attitude toward each job, his willingness to assume responsibility, his attentiveness to what goes on around him, whether observed firsthand or gleaned from the journals of his field—all of these things are factors determining how far the man may go.

We in the schools feel we have succeeded in our part of the task when we see our graduates attaining positions of responsibility in Industry or returning for advanced degrees and special courses. For then we believe we have helped to awaken in them something of the drive necessary for the achievement of those positions in which they can exercise their full capabilities.

BLAKE R. VAN LEER,
President, Georgia Institute of Technology

X-RAYS AT WORK FOR INDUSTRY

By R. A. YOUNG*

X-rays are a potent tool of industry, both in its research and in its control of product quality. This article describes the three major x-ray techniques and discusses some of their industrial applications.

Almost everyone is familiar with the medical applications of x-ray technology. Fewer people realize that x-ray methods constitute powerful tools for industry. This article is an attempt to describe briefly, and in general terms, some of the more important uses of x-rays.

There are three major techniques for utilizing x-rays: x-ray diffraction; x-ray spectroscopy; and radiography and irradiation, sometimes called radiology. Of these three techniques, x-ray diffraction has contributed most significantly to industrial research, although radiology, because of its wider use, is better known. Until quite recently x-ray spectroscopy has been almost exclusively a research tool.

SPECTROSCOPY

In its industrial applications x-ray spectroscopy is frequently referred to as "fluorescence analysis" because the sample is made to fluoresce under x-radiation. The sample absorbs the x-ray energy impinging upon it and then emits x-rays in wave lengths characteristic of the sample. Just as in optical or microwave spectroscopy, the wave lengths that can be emitted are associated with the energy levels in the sample. In this case the wave lengths are in the x-ray region and the energy levels are those associated with the tightly bound electrons. Thus, x-ray spectroscopy permits study of the energy levels deep within atoms, and adds to the knowledge of atomic structures gained from optical spectroscopy.

The radiation emitted from a sample in the optical region is dispersed by a prism or a diffraction grating in order that its wave lengths may be determined. The radiation emitted from a sample in the x-ray region is dispersed by the x-ray analogue of a diffraction grating, a crystal. The crystals used are chosen for their perfection, for their low absorption and for the accuracy with which their crystallography is known. Very satisfactory crystals can be obtained, and the wave lengths emitted by the sample can be determined quite accurately. Just as in optical spectroscopy, the wave lengths found from a given sample may be compared with those known to be produced by the various atoms, and both the kinds of atoms present and their relative amounts may be determined. One of the greatest advantages of x-ray spectroscopy is that it works best with the elements of or near the transition series, for the optical spectra of these elements are very complex.

X-RAY DIFFRACTION

In 1912 M. von Laue suggested that since the wave lengths of x-rays were of the same order of magnitude as the distances between atoms in solids, then x-rays ought to be diffracted by crystalline solids in much the same way that light waves are diffracted by a diffraction grating. Friedrich and Knipping soon showed experimentally that this was true, and the door to the investigation of the atomic domain was ajar. Long lines of illustrious names have followed ever since, each man pushing the door a little further open. One of the first and most heavily contributing of these men was Sir W. H. Bragg,

*Research Physicist.

Figure 1. Diffraction pattern of powdered tungsten carbide. Variation in intensity of lines stems from fact carbon atoms do not scatter x-rays as strongly as tungsten atoms do. Uniform intensity of individual lines over their entire lengths indicates random orientation of crystallites.

who showed that the diffraction of x-rays obeyed the relation

$$n\lambda = 2\ d \sin \theta$$

where n is an integer, λ is the wave length of the x-radiation, θ is the angle of diffraction (frequently called the Bragg angle), and "d" is the interplanar spacing.

The term "d" perhaps needs further explanation. We ordinarily think of x-rays as being scattered by atoms or groups of atoms within a crystal. We think of a crystal as being composed of a great number of these scattering points all neatly arranged in a perfectly periodic fashion in three dimensions. In such an array of points, often called a point lattice or simply a lattice, one may draw a set of imaginary planes, all parallel, such that every point in the array will have a plane passing through it. Since the point array is periodic, the distance from one plane to its neighboring plane will be the same throughout the set of parallel planes. It is this distance that is called "d," the interplanar spacing, in Bragg's equation. Its optical analogue is the distance between lines in a diffraction grating.

Since, in drawing our set of parallel planes, we placed no requirement that the planes be oriented in any particular way with respect to the lattice, we could then draw an infinite number of such sets of planes, each set having a different "d" value. Only a very limited number of such sets are useful to us. The maximum possible "d" value is limited by the distances between points, and the minimum "d" value that can be observed is limited by the wave length of the x-rays used and the condition that θ cannot be greater than 90° in Bragg's equation. Thus, in most experiments we actually measure only on the order of 10 to 50 of the largest "d" values, even under the best conditions. This is usually adequate.

Considering again our sets of parallel planes, we see that the "d" values obtained from them will be determined by the point lattice, or in practice, by the positions of the atoms or groups of atoms in the crystal. Thus each kind of crystal will diffract x-rays of a given wave length at a different angle, θ, for each "d" value according to the Bragg equation. This set of angles will be characteristic of that particular kind of crystal for the wave length used. If we then place a photographic film in the path of the diffracted x-ray beams, there will be registered on the film the "diffraction pattern" of the crystal. In the case of a single crystal, the diffraction pattern will appear as a group of spots on the film. In the case of a polycrystalline material*, the diffraction pattern will appear as a series of concentric circles or a series of arcs on the film, depending upon how the film is placed with respect to the sample and the incident x-ray beam. By knowing the geometry of the arrangement and the wave length used, one may then calculate a set of "d" values for the material.

Figure 1 shows the diffraction pattern of powdered tungsten carbide. It is noted immediately that all the lines are not equally intense. Without going into detail, we can perhaps understand that this might be expected because carbon atoms do not scatter x-rays as strongly as tungsten atoms. Hence at certain diffraction angles the radiation scattered from the carbon atoms might be either subtracted from or added to that from the tungsten atoms, thus affecting the total diffracted intensities. This is one of the principal reasons for variations in diffracted intensities. Therefore, a knowledge of the relative intensities of the diffracted x-ray beams is very helpful in determining the nature of the diffracting material.

The "d" values and the relative intensities of the diffracted beams might be referred to as the classical information to be obtained from x-ray diffraction patterns because in using them we usually assume that the diffracting material has an ideal lattice, that is, perfect periodicity extending over an essentially infinite number of scattering points. We may ask ourselves now, what would be the effect upon the x-ray diffraction pattern if those conditions were not met? One answer is immediately apparent by analogy to the diffraction of light. If we use a grating so small that it contains relatively few lines, the diffracted beam of light is not sharply defined. Similarly, if we have

*Metals are normally polycrystalline.

Continued on Page 13

INDUSTRIAL NEEDS FOR RAW MATERIALS OF PLANT ORIGIN

By H. H. SINEATH* *and* PHILLIP M. DAUGHERTY**

New cash crops for the American farmer and domestic sources of currently imported industrial raw materials of plant origin are important needs of our economy. This article discusses Federally supported work now in progress at Georgia Tech in an effort to provide information on scarce foreign crops of chemurgic importance that can be grown in the United States.

In recent years shortages of many imported raw materials have harassed industry in this country and have contributed to higher prices for finished products. During times of emergency such as World War II and the present period of international unrest, supply problems have forcefully pointed out the need for a more stable source of such materials. Foreign control of the source both limits the amounts available and encourages inflationary speculation in world markets. The observed low purity of many imported products stems partly from imperfect removal of contaminants and partly from foreign practices of product dilution. All of these adverse factors place industry and the eventual consumer at an economic disadvantage. Consequently, the need for initiation or expansion of domestic production of these commodities has become increasingly clear.

In some cases the development of synthetic substances has alleviated undesirable supply conditions to some extent; but in others, where suitable substitutes have not been found, interest has centered in establishing domestic cultivation of botanicals from which the raw materials are derived. This interest in a domestic source is augmented by the desire of farmers and business men alike for a more stable agricultural economy. Crop diversification has been advanced as the answer to this problem. If more industrial raw materials were domestically produced by the farmer as cash crops, many current problems of surplus agricultural production could be eliminated.

In order to determine what the raw material needs of industry in this country are, a survey was initiated during 1951 at the State Engineering Experiment Station, Georgia Institute of Technology. The survey was designed to present a more comprehensive picture of the entire raw material situation and to serve as a guide in the introduction of plants to fill the needs. The program, which was sponsored by the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, was supported under the Federal Research and Marketing Act of 1946 which specifically authorizes research to discover, introduce and develop new and useful agricultural crops.

The survey consisted of two parts. The first was a review of periodical literature to determine the needs which have been recognized and to obtain information on new uses for plant products and on new plants suggested to fill specific needs. The second involved direct contact with industry to obtain first-hand information on the present supply situation and to get estimates on future or potential needs of plant-derived raw materials.

The complex nature of the information desired from the survey necessitated careful selection of the literature to be reviewed. Fifteen periodicals were selected; these included at least one publication from each important industrial field which uses plant-derived raw materials. These periodicals were reviewed from January 1, 1946, through December 31, 1951, and abstracts of articles on needs, sources, and uses were compiled.

The direct-contact-with-industry phase of the program was initiated by correspond-

*Research Engineer.
**Research Assistant.

ence with national industrial associations, research organizations and government laboratories. These sources suggested individual companies which might have information pertinent to the survey. These companies and others which could be assumed to use plant-derived raw materials were contacted. In all, representatives of about 600 organizations cooperated with the survey by correspondence, and personal interviews were arranged when it was indicated that they would be of value. In this way, users of plant-derived raw materials from all parts of the United States and in every major field of interest were included in the survey.

Numerous raw material needs were found that affect, either directly or indirectly, a major portion of American industry. In some cases suitable substitutes were uncovered, and in several instances information concerning new materials was found which should be of industrial value and of potential importance to the individual.

As an example, sperm oil, which is vitally important to steel processing industries as a high-speed and high-temperature lubricant, has been in critically short supply at various times in recent years. A shortage occurred during World War II when whaling expeditions were not permitted because it was necessary to use vessels previously engaged in the production of sperm oil for other purposes and because the lengthy ocean voyages necessary would have been subject to the perils of the sea and of enemy action. The erratic supply of this material has led to considerable interest in the development of a plant source for a substitute. Such a source would eliminate speculative financing of foreign whaling expeditions and insure a stable domestic supply of the material. Fortunately, the seeds of the *Simmondsia* plant, which grows wild in this country, have been found to contain a replacement for sperm oil. After the oil is removed from the seed, the residue is suitable for livestock feed and can be used in plastics. Of particular interest to many individuals is the fact that *Simmondsia* oil has exhibited an intense inhibitory action on the growth of tuberculosis bacilli in cultural media. This may provide a lead to the long-sought cure for tuberculosis. Another product of this potential ten million-dollar crop for the American farmer is a hard wax obtained by hydrogenation of the oil. This wax could be used in the preparation of polishing waxes and the manufacture of carbon paper. In addition, it might serve as a replacement, in certain uses, for the much-needed and high-priced carnauba wax now imported from Brazil.

The supply conditions of carnauba have greatly increased the demand for candelilla wax for use as a carnauba extender. Candelilla wax is collected from a weed that grows wild in Mexico. The imported material is often contaminated, and additional expensive processing is required before it can be used as an ingredient in numerous items from phonograph records to electrical insulators. This factor alone makes a domestic source desirable, and, since it grows wild in the semiarid regions of the Southwest, candelilla represents a possible three million-dollar crop for submarginal land.

Another oil of importance is perilla, some formulations of which possess several superior properties as protective coatings for particular uses. This oil was once widely used in the United States in the manufacture of paints, varnishes, linoleum and related products. Prior to World War II it was supplied largely from Manchuria, but it has been unobtainable from any source in recent years. Varieties of perilla have been introduced and successfully grown in this country. A mint known as Chia, native to northern Mexico, has seeds which yield an oil with practically the same characteristics as perilla. Since it has been estimated that about twelve million dollars worth of an oil of this type could be consumed annually in this country, any of these plants might possibly become valuable crops.

Another need affecting practically everyone is that for an insured source of fibers for paper making and cordage. Although there is a moderately ample supply of the necessary "long-fiber" cellulose, some paper manufacturers have been unable to obtain all that they could use. According to recent

Continued on Page 21

ELECTRIFICATION IN AEROSOL STUDIES

By BARTON L. HINKLE* and CLYDE ORR, JR.**

For some time Georgia Tech researchers have been conducting a project for the Chemical Corps to determine what effect, if any, various vapors and the ionization of air and these vapors have on the agglomeration of aerosols. This article describes their work and presents some of their data.

Thales of Miletus is credited with the first observation (about 600 B. C.) of electrical effects other than those due to atmospheric electricity. This philosopher found that amber rubbed with silk could attract bits of straw and lint. Mottelay, in a bibliographic history of electricity and magnetism, suggests that considerable knowledge of atmospheric electricity existed as early as the time of Moses and that Solomon's temple was built with sharp gold points on the roof, which were connected to the earth by metal. Today everyone is familiar with manifestations of static electricity such as the crackling or sparking that occurs when hair is combed in cold, dry weather, the sticking together of sheets of paper, the tenacity with which dust and lint adhere to clothes, and the ability of chalk particles to stick to a blackboard.

Several investigators in the field of electrification have theorized that the stability of a dust cloud (i.e., the ability of the cloud to remain in suspension) may be attributed to mutual repulsion between charged particles. Some observers believe that the sudden falls of rain noted just after lightning discharges can be explained on the basis of a change in the electrification of the atmosphere. Thus, the small drops, kept apart by mutual repulsion, are discharged during the lightning flash; subsequent coalescence of the droplets takes place, and the large drops, too heavy to remain in suspension, fall to the earth.

Static electricity is related not only to the nature and size of the individual particles but also to the relative humidity of the surrounding air. In fact, humidity control is

*Research Assistant.
**Research Engineer.

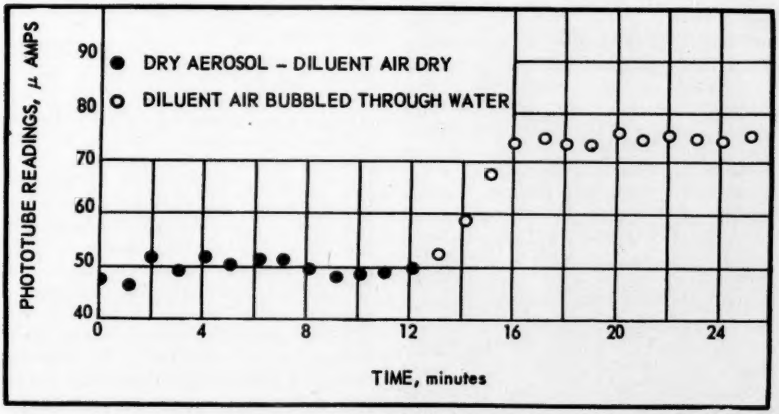


Figure 1. An increase in particle size with humidification of the suspending air is indicated by this chart of light scattering by an ammonium choride aerosol in dry air and in air of 40 per cent relative -humidity.

widely used in industries to effect dissipation of electric charges which would otherwise constitute a nuisance and, in many cases, a hazard.

Static electricity has been firmly established as a source of dust ignition. The origin of many costly disasters such as explosions in grain elevators, coal mines, industrial grinding and threshing operations, etc., has been traced to the electrification produced by aerosol systems. The frequency of the electrical displays which accompany dust storms in the Sahara desert has been attributed to the prevailing arid climate, although high temperature is another factor known to contribute to high voltage gradients. Some investigators have reported that no charge is carried by dust particles in a moving air stream when the relative humidity of the air exceeds 65 per cent, and it is generally conceded that grounding and high humidities are by far the most effective means of combating the production of static electricity. While innumerable illustrative cases of dust explosions and fires in the chemical industries are available, the following example amply indicates the importance of regulated humidity. Federal investigation of frequent fires at cotton gins during the summer of 1917 revealed that the fires occurred almost entirely during dry weather and that, in such weather, static electricity was often so prevalent that it was impossible to handle or approach any part of the machinery. Cotton would stick in the lint flues, causing clogging of the lines. Often sparks four to six inches long could be drawn from the machinery, and six fires a day were not uncommon. Humidification of the air effectively put an end to these disturbances, and practically no fires have since occurred at gins where humidification is employed.

In view of the powerful electrical forces which sometimes accompany dust clouds and the charges associated with the surfaces of the individual particles, it is apparent that a study of fine-particle matter would be incomplete without thorough analysis of the relation of these charges to experimental results.

From these considerations, one might predict that the addition of water vapor to a charged aerosol system would alter the stability of the system. In a previous article in **The Research Engineer,** DallaValle and Lane presented electron photomicrographs showing increased aggregation of ammonium chloride particles with increasing relative humidity of the surrounding air. Moreover, studies indicate that the amount of aggregation is somewhat dependent on the manner in which water vapor is introduced in the suspending air. Evidence has been presented elsewhere showing that air, when bubbled through certain liquids, acquires a charge by removing ions from the surface of contact. Pure water imparts a negative charge to the air, while certain other liquids may impart a positive charge and some liquids no charge at all. The amount and nature of the charges are related to the surface tension, the dielectric properties and the "activity" of the liquid, where "activity" refers to the ability of the liquid to impart charges. Evaporation of water, on the other hand, does not result in any noticeable manifestation of electricity, nor is any electrification produced by bubbles due to boiling.

With this evidence at hand, Georgia Tech investigators have been conducting experiments to determine the effect of vapors on the aggregation of an aerosol by varying the method of vapor production and by ionizing the air and vapors.

A brief description of the equipment employed will facilitate discussion of the results. The principal element of the aerosol generating equipment is a LaMer generator, in which the substance to compose the solid phase of the aerosol (e.g., ammonium chloride crystals) is vaporized. Dry air is passed through a spark gap to produce ions which will serve as nuclei for the condensation of this vapor, and then the ionized air is introduced into the vapors. The mixture of air, ions and vapors of the solid substance is passed to another heating compartment held at a somewhat higher temperature to ensure thorough vaporization; then it is led upward through a condensing column where the vapors, as they cool, condense on the ions. The number and size of the aerosol particles thus formed may be controlled through regula-

Continued on Page 19

PHOTOGRAPHIC JOB STUDY

By ROBERT N. LEHRER* *and* JOSEPH S. DWYER**

Substitution of photography for personal observation aids the industrial engineer in obtaining job data over extended periods of time. The technique employed, together with examples of its use, is described in the following article.

Photographic job study makes possible the collection of job data over extended periods of time much more economically than the data could be gathered by personal observation, thus making feasible some analyses that otherwise would be too costly. This technique utilizes photographic observations, made periodically and automatically, followed by analysis of the photographic record at a later, more convenient time. Among the types of job study most conveniently undertaken photographically are the analysis of equipment utilization, material and traffic flow, crew coordination, machine interference, balance of line activity, allocation of job duties, machine and work assignments, delay occurrences and other activities which must be observed over a period of time.

This technique allows more flexibility than other photographic methods and tends to approximate the random-check or ratio-delay job study procedures by means of photographic records. It offers the advantages of a permanent photographic record combined with extended coverage and simultaneous observation of more than one activity. Furthermore, it allows lengthy studies to be carried out with maximum convenience and economy. The technique stemmed from the necessity to study work that could not be directly observed for sufficiently long periods of time to yield reliable data.

The equipment required for photographic job study consists of a movie camera capable of taking individual exposures, a mechanism for actuating the camera to take the individual exposures and a timing unit to energize the drive mechanism periodically. An electrically driven 16-mm GSAP camera and a synchronous motor timer mounted in a protective case, as shown in Figure 1, were used for trial investigations. This equipment was not ideal, for several pictures were exposed each time the camera drive was energized, but the results were satisfactory and the equipment had the advantage of low cost.

Before gathering data by photographic means, it is necessary to make a preliminary analysis to ascertain that the desired information can be recorded by the camera. This preliminary analysis insures easy and accurate classification of activity from the film record. The work area should be well defined and include all of the pertinent activity. The types of activity to be investigated should be clearly and precisely defined. The analyst must become familiar

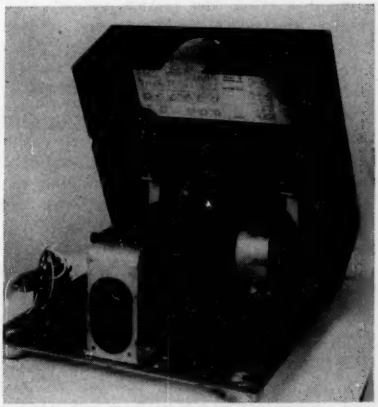


Figure 1. The 16-mm camera used in the studies was triggered by the timing device on the right.

*Associate Professor of Industrial Engineering.
**Formerly Associate Professor of Industrial Engineering, Georgia Tech. Now Head of the Department of Industrial Engineering and Drawing, Texas Technological College.

with the work being photographed so that he will be able to classify the activity accurately when the film record is examined. Peculiarities of the work situation should be noted for they are helpful in obtaining accurate analysis data.

Two analysis situations will be discussed here in order to illustrate how the photographic job study technique can be used. The examples do not present all the aspects of this technique, but they do indicate the general procedure involved.

The first study to be discussed is a simple and straightforward use of the technique The problem developed as a result of student complaints concerning the check-cashing and banking service offered by the campus Cashier's office. The administration felt that the situation should be analyzed in an objective fashion to determine if the student suggestions that additional personnel be assigned to this activity were justified.

A preliminary study indicated that information was needed on the number of students waiting for service, the absence or presence of the cashier and the relationship of these factors with the time of day and the day in the week and month. The camera unit was mounted in the Cashier's office, situated so that the service counter, the cashier, the waiting students and a wall clock were recorded. Pictures were then taken at five-minute intervals over an extended period of time.

When sufficient pictures had been taken to obtain a reliable record of the cashier activity and student delays involved, the film was processed and each exposure examined. A tabulation of the delays involved in this activity led to the conclusion that it would be uneconomical to assign more than one full-time cashier. The peak loads could be satisfactorily handled by borrowing additional help from other assignments.

The second study is described to illustrate how photographic job study can be used to help gather information for job analysis and evaluation purposes. The job studied was a clerical assignment consisting of varied general duties in a departmental office. A preliminary analysis was made to ascertain

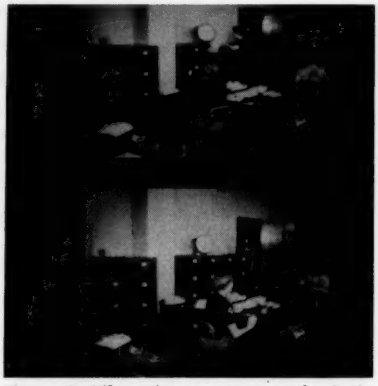


Figure 2. These frames are typical of the photographs taken for job analysis of office work.

the main characteristics of the job and to determine the activity breakdown for the photographic study. The duty classifications were established so that analysis of the film record could be made with certainty as to the recorded activity. These were:

1. Typing (facing typewriter at left side of desk)
2. Seated at desk (facing forward, occupied)
3. Standing at desk (facing forward, occupied)
4. At files (beyond desk)
5. At phone (to right of desk)
6. Talking (at desk)
7. Walking (to and from files)
8. Idle
9. Gone from desk (not in camera view)

All of these classifications would show the secretary in the picture at a specific location, with the exception of No. 9, "Gone from desk." This category would include all activity requiring the secretary to be away from the area of camera view plus any voluntary absences from the scene.

The camera unit was mounted in the office, and exposures were made at five minute intervals for a ten-day period. After processing, the films were examined, ex-

Continued on Page 18

SUBJECT AND AUTHOR INDEX

MAY, 1951-MARCH, 1952

A

A-C network analyzer, S '51, 17
Aerosol studies at Georgia Tech, N '51, 9
Aerosols, see also Fine particles,
———————, atmospheric effects, N '51, 22
———————, meteorological aspects, N '51, 10
———————, physiological action, N '51, 9, 22
———————, rainmaking, N '51, 10
———————, techniques of aggregation studies, Mr '52, 8
Aggregation of aerosols, Mr '52, 8
Air friction, role in textile spindle power consumption, My '51, 14
Allethrin, Mr '52, 23
Amino acids, chlorination, S '51, 15
Ammi visnaga, Mr '52, 22
Analysis of the characteristics of a panel heating system in a public library, My '51, 13
Application of solar radiation to comfort cooling, My '51, 13
Application of the electron microscope, N '51, 5
Appreciation of research, Mr '52, 2
Avent, John M.,
———————, industrial engineering and sound management practices, My '51, 9

B

Bagasse, Mr '52, 22
Bamboo, Mr '52, 22
Belser, R. B.,
———————, economical high-temperature infra-red oven, Ja '52, 9
Biophysics, Ja '52, 11

C

Candelilla wax, Mr '52, 6
Cavendish laboratory, Ja '52, 8
Cellulose, "long-fiber", Mr '52, 6
Chia-seed oil, Mr '52, 6
Chlorination of amino acids, S '51, 15
Coal, distillation, My '51, 5
Construction,
———————, nailed, My '51, 11
———————, ring-connector, N '51, 7
Coriander oil, Mr '52, 22
Correlation function,
———————, applications, My '51, 7, 22
———————, definition, My '51, 8
Cox, Fred W., Jr.,
———————, product research as an aid to southern industry, Ja '52, 3
———————, State Engineering Experiment Station 1950-1951, S '51, 7
Crop diversification, Mr '52, 5
Crystal-controlled high frequency oscillator circuits, S '51, 16
Crystal orientation, Mr '52, 15
Cyclone,
———————, liquid, S '51, 5
———————, ———————, classifier, S '51, 6
———————, ———————, industrial applications, S '51, 5, 23
———————, ———————, separator, S '51, 22

D

DallaValle, J. M.,
———————, aerosol studies at Georgia Tech, N '51, 9
Daugherty, Philip M.,
———————, industrial needs for raw materials of plant origin, Mr '52, 5
Distillation of wood and coal by the fluidized powder process, My '51, 5
Dixon, Fred,
———————, philosophies concerning engineering problems in medical research, Ja '52, 11
Draft of engineers, N '51, 15, 20
Drugs, Mr '52, 22
Dwyer, Joseph S.,
———————, photographic job study, Mr '52, 9

E

Economical high-temperature infra-red oven, Ja '52, 9
Education,
———————, graduate, S '51, 2
———————, of engineers, My '51, 2
Electricity, static, Mr '52, 7
Electrification in aerosol studies, Mr '52, 7
Electromagnetic waves, propagation, S '51, 16
Electron micrographs,
———————, calibration, N '51, 11
———————, third dimension, N '51, 12
Electron microscope,
———————, applications, N '51, 5
———————, sample preparation, N '51, 14
Electronics, S '51, 16
Endsley, Joseph Wendell,
———————, analysis of the characteristics of a panel heating system in a public library, My '51, 13
Engineering Experiment Station, see State Engineering Experiment Station
Engineers,
———————, draft, N '51, 15, 20
———————, number estimated, My '51, 14
———————, number needed, N '51, 14, 15
Ergot, Mr '52, 22
Essential oils, Mr '52, 22
Experiment Station, see State Engineering Experiment Station

F

Faculty research, My '51, 3
Fibers, Mr '52, 6
Fine particle research, see also Aerosols, S '51, 14
Flooring material, trowel-applied, Ja '52, 5
Fluidized powder process of distillation, My '51, 5
———————, difficulties, My '51, 18
———————, research, My '51, 18
Fluoroscopy, see Radiography

G

Government-financed research, S '51, 2

H

Hainlin, Albert Wellington,
———————, the application of solar radiation to comfort cooling, My '51, 13
Helicopter, S '51, 18
Hinkle, Barton L.,
———————, electrification in aerosol studies, Mr '52, 7
Honnell, M. A.,
———————, television—product of research, S '51, 3
Hydraulics, S '51, 18
Humidity, control of static electricity, Mr '52, 7
———————, effect on aerosols, Mr '52, 7

I

Individual faculty research, My '51, 2
Industrial engineering and sound management practices, My '51, 9
Industrial needs for raw materials of plant origin, Mr '52, 5

Infra-red radiation, Ja '52, 9
———————, oven heated by, Ja '52, 9
———————, reflection characteristics of metals, Ja '52, 10
Insecticides, Mr '52, 23
Institutes,
———————, Centre Nationale de la Recherche Scientifique, Ja '52, 20
———————, Institute for Low-Temperature and Technical Physics, University of Louvain, Ja '52, 23
———————, Kamerlingh Onnes Physical Institute, University of Leiden, Ja '52, 22
———————, Physical Institute, University of Erlangen, Ja '52, 22
International Conference on Low-Temperature Physics, Ja '52, 8
International Congress of Refrigeration, Ja '52, 20

J

Jackson, M. W.,
———————, long-term load test of a ring-connector truss design, N '51, 7
———————, long-term load test of nailed construction, My '51, 11
Job study, photographic, Mr '52, 9
Johnson, J. W.,
———————, an economical high-temperature infra-red oven, Ja '52, 9
Jute, Mr '52, 22

K

Kenaf, Mr '52, 22
Khellin, Mr '52, 22

L

Laboratory,
———————, Cotton, Ja '52, 20
———————, Royal Society Mond (Cavendish), Ja '52, 8
Lane, J. C.
———————, aerosol studies at Georgia Tech, N '51, 9
———————, a resilient flooring and surfacing composition, Ja '52, 5
Lehrer, Robert N.,
———————, photographic job study, Mr '52, 9
Lewis, H. C.,
———————, distillation of wood and coal by the fluidized powder process, My '51, 5
Liquid cyclone, see Cyclone
Load test,
———————, nailed construction, My '51, 11
———————, ring-connector truss, N '51, 7
Long-term load test of a ring-connector truss design, N '51, 7
Long-term load test of nailed construction, My '51, 11
Low-temperature research in Europe, Ja '52, 7

M

Management practices, My '51, 9
Measurement, basic considerations, Ja '52, 12
Mechanical Engineering, digests of graduate theses, My '51, 13
Medical equipment, principles of design, Ja '52, 11
Medical research, design of equipment, Ja '52, 11
Metal films,
———————, resistivities, Ja '52, 22
———————, structural and electrical properties at low temperatures, Ja '52, 23
Metals, infra-red reflection characteristics, Ja '52, 10
Micromeritics, see Aerosols and Fine particles
Microorganism survival at low temperatures, S '52, 14
Microradiography, Mr '52, 17
Microscope, electron vs. optical, N '51, 5
Miller, Wallace J., obituary, N '51, 24
Moder, Joseph J., Jr.,
———————, recent industrial application of the liquid cyclone, S '51, 5
Mond Laboratory, Ja '52, 8
Mortar for marble, tile, etc., Ja '52, 6

N

Nailed joints, My '51, 11
New roles for the universities in the defense program, My '51, 3
Network analyzer, S '51, 17
Nomographs, S '51, 17

O

Oils,
———————, Chia-seed, Mr '52, 6
———————, coriander, Mr '52, 22
———————, essential, Mr '52, 22
———————, perilla, Mr '52, 6
———————, sesame, Mr '52, 23
———————, Simmondsia, Mr '52, 6
———————, sperm, Mr '52, 6
———————, vegetable, S '51, 14
Orr, Clyde, Jr.,
———————, electrification in aerosol studies, Mr '52, 7
Oscillator circuits, high frequency crystal-controlled, S '51, 16
Oven,
———————, infra-red, Ja '52, 9
———————, ———————, temperature measurement, Ja '52, 10

P

Paint exposure studies, S '51, 15
Parachute fabric studies, S '51, 15
Particular size, x-ray diffraction determination, Mr '52, 15
Patching compound, Ja '52, 5
Peanuts,
———————, industrial engineering survey, S '51, 18
———————, processing, S '51, 17
Perilla oil, Mr '52, 6
Perlin, J. E.,
———————, the correlation function, My '51, 7
Philosophies concerning engineering problems in medical research, Ja '52, 11
Photographic job study, Mr '52, 9
Plant-derived raw materials, Mr '52, 5
Potato chips, shelf life, S '51, 15
Product research as an aid to southern industry, Ja '52, 3
Pyrethrum, Mr '52, 23

R

Radar, S '51, 16
Radiography, Mr '52, 3, 17
Radiology, Mr '52, 3, 16
Rainmaking, N '51, 10
Rare-earths, separation and purification, Ja '52, 21
Raw materials from plants, S '51, 16; Mr '52, 5
Recent industrial application of the liquid cyclone, S '51, 5
Refrigeration, International Institute of, 8th International Congress, Ja '52, 20
Research,
———————, applied, Ja '52, 4, 16
———————, appreciation, Mr '52, 2
———————, development in U. S., N. '51, 4
———————, faculty, My '51, 2
———————, federal appropriations, N '51, 19
———————, fine particle, S '51, 14
———————, for future prosperity, Ja '52, 3
———————, fundamental, Ja '52, 4
———————, ———————, amount necessary, N '51, 23
———————, ———————, government-financed, My '51, 4, 14
———————, government-financed, S '51, 2
———————, in the south, My '51, 16; Ja '52, 3
———————, industrial, Ja '52, 3
———————, institutes, Ja '52, 4, See also Institutes
———————, low-temperature, Ja '52, 7
———————, manpower, S '51, 2

——————, medical, Ja '52, 11
——————, military, My '51, 3
——————, nonprofit, Ja '52, 24
——————, product, Ja '52, 3
——————, profits from, N '51, 2, 23
——————, sponsored, N '51, 16, 17
——————, television, S '51, 3
——————, university, N '51, 3
Resilient flooring and surfacing composition, Ja '52, 3
Ring-connector joints, N '51, 7
Rosselot, Gerald A.,
——————, State Engineering Experiment Station 1950-1951 S '51, 7
Royal Society Mond Laboratory, Ja '52, 8
Ryania, Mr '52, 23

S

Sabadilla, Mr '52, 23
Scott, Charley,
——————, specific heat lag in gases, My '51, 13
Selling research, N '51, 2
Sesame oil, Mr '52, 23
Sesamine, Mr '52, 23
Shadowing techniques for electron micrographs, N '51, 11
Simmondsia, Mr '52, 6
Sixeath, H. H.,
——————, industrial needs for raw materials of plant origin, Mr '52, 5
Smoke abatement, N '51, 22
Southern industry, Ja '52, 3
Specific heat lag in gases, My '51, 13
Spectroscopy, x-ray, Mr '52, 3
Sperm oil, Mr '52, 6
State Engineering Experiment Station,
——————, 1950-1951, S '51, 7
——————, budget, S '51, 8
——————, development of flooring and surfacing composition, Ja '52, 5
——————, facilities, S '51, 9
——————, organizational chart, N '51, 18
——————, personnel, S '51, 9
——————, research for Southern industry, Ja '52, 17
——————, service activities, S '51, 12
——————, survey of raw material needs of industry, Mr '52, 5
——————, x-ray laboratory facilities, Mr '52, 3
Stucki, Arthur Conrad,
——————, air friction—its role in textile spindle power consumption, My '51, 14
Surfacing material, Ja '52, 5

T

Television, S '51, 17
——————, color, S '51, 20
——————, history, S '51, 3
——————, special applications, S '51, 21
——————, product of research, S '51, 3
Theses, digests of graduate, mechanical engineering, My '51, 13
Time standards, predetermined, My '51, 10
Tooke, W. R., Jr.,
——————, a resilient flooring and surfacing composition, Ja '52, 5
Trusses, nailed, My '51, 23
Trusses, ring-connector, N '51, 7
Tungsten carbide, diffraction pattern, Mr '52, 3, 4, 15

U

Universities,
——————, new roles in the defense program, My '51, 3
——————, their relationship to research and development, N '51, 3

V

Van Leer, Blake R.,
——————, compensation for engineers, Ja '52, 2
——————, education of engineers, My '51, 2; S '51, 2; Mr '52, 2
——————, graduate education, S '51, 2
——————, in management, My '51, 2
——————, universities and their relationship to research and development, N '51, 3
Vegetable oils, S '51, 14
Very low-temperature research, S '51, 13

W

Wage incentives, My '51, 10
Walker, Eric A.,
——————, new roles for the universities in the defense program, My '51, 3
Waxes
——————, candelilla, Mr '52, 6
——————, carnauba, Mr '52, 6
——————, Simmondsia, Mr '52, 6
Wood distillation, My '51, 5; S '51, 16
Woodward, L. A.,
——————, applications of the electron microscope, N '51, 5
Watermelon rinds, sectioning and preparing, S '51, 18

X

X-Ray,
——————, diffraction, Mr '52, 3
——————, particle size measurement, Mr '52, 15
——————, radiography and irradiation, Mr '52, 3, 17
——————, radiology, Mr '52, 3, 16
——————, therapy, Mr '52, 17
——————, spectroscopy, Mr '52, 3
X-rays at work for industry, Mr '52, 3

Y

Yarns, physical study, S '51, 15
Young, R. A.,
——————, x-rays at work for industry, Mr '52, 3

Z

Ziegler, W. T.,
——————, low-temperature research in Europe, Ja '52, 7

X-RAYS AT WORK FOR INDUSTRY

Continued from Page 4

too few scattering points, we may expect the diffracted x-ray beam to be ill-defined. In a powder pattern, such as the one shown, the diffraction lines will be broadened by these effects and will not show the sharp edges that they do in this pattern of tungsten carbide. The effect of imperfect periodicity in the lattice may also cause broadening and poorer definition of the lines, but, in addition, it will affect the "line shape." The "line shape" may be defined as the shape of the curve which is obtained by plotting diffracted intensity vs. θ over a small region which includes the center of a diffracted beam. Ideally, we would expect

such a curve to fall off equally on either side of the maximum, but this need not be the case. In any real crystal the distance between planes will probably not be exactly the same for every pair of planes in the whole set. The value that we write down as the "d" value for this set will really be an average. In the curve of line shape the maximum will occur at a position that exactly satisfies Bragg's equation for this average "d" and the wave length used. But since other "d" values, slightly different from the average, do exist, then even though our wave length is truly constant, we find that some diffraction does take place at θ values slightly different from the θ corresponding to the maximum in our curve. The curve of line shape then actually represents the distribution of the individual "d" values about the average and thus yields information about the way in which the actual crystal lattice differs from an ideal lattice.

We have now discussed four distinctly different kinds of information about a crystal that can be obtained from x-ray diffraction patterns: the "d" values, the relative intensities, the line breadth, and the line shape. We have endeavored to understand something of the significance of each in terms of the nature of the diffracting material. Let us now go on to discuss some of the ways in which this information is applied to the solution of problems.

X-RAY DIFFRACTION APPLICATIONS

Historically, only the "d" spacings and the relative intensities were considered at first. Under ideal conditions this information is sufficient to determine completely the crystal structure of materials which crystallized in the cubic, hexagonal or tetragonal classes. This includes most metals and a large number of the other elements and their compounds. As new techniques for obtaining and interpreting various kinds of diffraction patterns have been developed, it has become possible, at least theoretically, to determine completely the crystal structure of any single crystal. However, practical difficulties, such as the cost of adequate equipment and the tremendous amounts of time necessary, have so far prevented complete determination of the structure of more than a small portion of the various kinds of crystals to be found in the world about us.

There are many reasons why complete determination of a crystal structure is desirable. A knowledge of crystal structures is frequently useful to the scientist in his efforts to determine why materials behave as they do. It is particularly useful to the theoretical chemist who wants to know bond angles, bond distances, atomic and ionic radii, etc., in order to synthesize a material.

Even though our information may not be sufficient for a complete determination of the crystal structure, it may still be extremely valuable. Perhaps the reader has heard of "finger-printing the compounds." This is a reference to the fact that the diffraction patterns of no two substances are exactly alike, hence a simple measurement of the "d" values and only a rough measurement of the relative intensities in the powder diffraction pattern of a crystalline material are sufficient to identify it accurately. Furthermore, the observed pattern need not be due to one substance alone; instead, it may be a composite of two or more diffraction patterns, each of which is characteristic of a different substance. With reasonably good equipment and some care, a quantitative determination of the amounts of the various materials present may be carried out, usually to an accuracy of $\pm$ 1-5 per cent. Trace amounts of well formed foreign crystals in a sample may sometimes be detected even though they account for no more than one-tenth of one per cent of the sample.

If only the crystal lattice type is known, and if samples are made to produce diffraction patterns under appropriate conditions, measurement of the "d" values alone may lead to the determination of such things as the coefficient of thermal expansion for the material and the expansion or contraction of the lattice upon addition of a solute, such as occurs in alloying. Measurement of the "d" values alone is also generally sufficient to detect a change in crystalline phase.

One of the most widespread uses of x-ray diffraction is determining the orientation of the various rows (or planes) of atoms within

the crystal with respect to outside dimensions of the crystal. This is called "crystal orientation." It is so widely used in the process of cutting blanks for quartz crystal oscillators that x-ray units designed for this purpose alone find a good market.

Just as the orientation of a large single crystal may be determined, as mentioned in the preceding paragraph, so it is sometimes possible to determine something about the orientation of the crystallites* in a polycrystalline material. In this case one determines not the orientation of any individual crystallite, but rather the tendency for more of the crystallites to be oriented in one particular fashion than in any other. If, in a polycrystalline sample such as the usual powder sample, the orientation of the crystallites is truly random, the lines in the diffraction photograph will be of uniform intensity over their length. Figure 1 illustrates this case. If the film is so placed that the diffraction pattern is a series of concentric circles, then each circle will display uniform intensity over its circumference. However, if the orientation is not random, then certain diffraction directions will be preferred to others. The lines may show spottiness, or the circles may show arcs of greater intensity with "washed out" regions between the ends of the arcs in a given circle. These effects are said to be due to "preferred orientation" and are useful in two ways. First, one may calculate the direction of the preferred orientation and relate it to such things as the substrate on which crystallization took place, directional strain in the material (e.g., stretched rubber displays a preferred orientation as do most strained fibers), or other factors influencing the orientation of the crystallite. Second, if the observed directions of preferred orientation do not seem to be related to any factors influencing the orientation of the crystallites, one may conclude that the spottiness is due simply to large crystallites and, by calculating the number of such crystallites per unit volume of the material, arrive at an average "grain size" of the crystallites.

*Crystallite here refers to a small single crystal, a multitude of which go to make up even a small sample of a polycrystalline substance.

Under usual conditions of production, spottiness occurs in powder diffraction patterns only when the average size of crystallites, or grains, is larger than about 0.01 mm. From this size down to about 2×10^{-4} mm, the rings or lines in a powder diffraction pattern remain of uniform intensity and constant breadth. Below this size, however, each crystallite no longer contains enough scattering points to act as a high quality diffraction grating, and line broadening occurs. By measuring the broadening effect, one may again calculate the grain size. Thus, x-ray diffraction is useful in determining grain sizes in the region above 0.01 mm and in the region below about 2×10^{-4} mm.

In the foregoing discussion it is important not to confuse crystallite size and grain size with particle size. They may be quite different things, and they frequently are. In x-ray diffraction work a crystallite, or grain, is conceived of as being a region over which the periodicity of the scattering point arrangement is subject to only the slightest deviations. Several such regions may cling together to make up a particle. For many years it has been recognized that particle sizes might be determined from the measurement of the low-angle, incoherent x-ray scattering from a finely divided sample. Recently, successful correlations of such measurements with electron microscope measurements on the same samples have been reported. The error in either grain size or particle size determinations rarely, if ever, is less than 20-30 per cent. Yet very useful information may be obtained from these measurements, particularly when they are supplemented by electron micrographs.

It was mentioned in the general discussion of x-ray diffraction that imperfections in the crystalline lattice could cause broadening of the lines in the powder diffraction pattern. One type of such imperfection is the small changes introduced in the individual "d" values (which are averaged together to give the "d" value for that particular diffraction line) by strain in the lattice. While it is rather difficult quantitatively to relate the amount of broadening of the lines to the amount of strain, qualitative observations can be made quite readily. These give con-

siderable valuable information. For example, the depth of cold-work may be determined by successively taking x-ray diffraction patterns and etching off thin layers of the surface of a material until the diffraction pattern no longer shows any change as a result of etching, i.e., until the cold-worked layer has been removed.

By noting which lines in the diffraction pattern show the greatest broadening, and hence the greatest strain, the planes of slippage in a crystal may be determined, even though the individual crystals may be extremely small. This information could conceivably lead to the selection of the proper alloying material to give greatest strength or to the detection and reproduction of the strained condition that would correspond to the particular hardness desired.

So far, we have discussed a few of the applications which depend upon the existence of a lattice structure which has, at most, rather slight imperfections. There also exists a whole class of applications which might be described as the x-ray study of amorphous materials. Glasses, liquids, gases, rubber, waxes, starches, various high polymers, textiles and biological specimens are examples of materials that have been successfully studied by x-ray diffraction methods but which do not possess a well defined lattice. In general, the x-ray diffraction patterns of these substances are obtained with the techniques used for polycrystalline materials. The diffraction lines so obtained are usually very broad and poorly defined, yet each line still possesses a center of density which can be measured and interpreted as corresponding to a preferred "d" value in the material. Thus, in the case of a diatomic gas, the "d" value obtained from the strongest line in the pattern (and perhaps the only line) would be interpreted as the average distance between atoms in the molecule. In the case of fibers, rather large "d" values are obtained and are interpreted as corresponding to long-range ordering in the fiber. This happens to be a particularly interesting application, since the results obtained by x-ray diffraction indicate a periodicity so large that it can be, and has been, checked with the electron microscope.

In addition to determining "d" values for amorphous substances, it is also possible to study orientation effects in much the same way as preferred orientation is studied when dealing with materials having a regular lattice. Thus, one can note something of the way that the molecules in fibers tend to line up under strain. X-ray diffraction is also used to determine the relative amounts of amorphous and crystalline material in such things as cellulose (e.g., cotton fibers) and, more recently, ceramics.

We have now discussed something of the theory of x-ray diffraction and several of its applications. These are not, by any means, all of the applications that are made of x-ray diffraction, nor are they necessarily the most important applications of their kind in every case. Rather, these applications have been selected more or less at random in order to indicate the scope of x-ray diffraction studies. A more extensive list of specific applications can be found, among other places, in General Electric Company's Publication No. 7A-560B, available from the company on request.

As we have seen, x-ray diffraction methods may be applied to advantage in a great many fields of research and industry. The applications are, in fact, so numerous and so varied that it is almost impossible for any one person to be thoroughly familiar with all of them. Thus, it is generally necessary for the x-ray diffraction specialist to work rather closely with a specialist in the particular field of application. For example, if a problem is of a metallurgical nature, the x-ray diffraction specialist works with a metallurgist in its solution. On the other hand, certain applications, such as routine identification of compounds in a control laboratory or orientation of quartz crystals prior to cutting oscillator blanks, do not pose any new difficulties and are entrusted to technicians with relatively little training in the x-ray method.

RADIOLOGY

Early in the history of x-rays it was discovered that they were more strongly ab-

sorbed by some materials than by others. This discovery resulted in the most used and most widely known applications of x-rays: medical and industrial radiography and fluoroscopy. The discoverer of x-rays, Wilhelm Roentgen, mentioned in his first published report of the new x-rays that when he held his hand between the source of the x-rays and a fluorescent screen the outlines of the bones in his hand could be seen upon the screen. The medical profession was quick to appreciate the importance of this discovery and to apply the methods to medical problems. By substituting a photographic film for the fluorescent screen a permanent record was made which could be studied at leisure and in more detail. Thus, for the first time, the doctor had a means by which he could actually look inside his patient without having to operate. Such applications are called medical radiography.

It was also early discovered that x-rays ionized some of the atoms they encountered and this resulted in biological effects that are sometimes beneficial and sometimes harmful. It frequently happens that diseased tissue is more strongly affected by x-rays than is healthy tissue. This has resulted in the field known as x-ray therapy. The whole field of medical applications of x-rays, both radiography and therapy, is designated by the term "medical radiology," and the specialist in the field is known as a "radiologist." Although the field of medical radiology is extremely interesting and of vast benefit to humanity, it is medical in nature and will not be discussed further here.

Industrial radiography, on the other hand, includes those radiographic applications which are not of a medical nature. Its theory is extremely simple compared with the theory of x-ray diffraction, being simply that the more strongly absorbing regions of the object being x-rayed allow fewer x-rays to reach the photographic film (or fluorescent screen) and hence produce an underexposed region of a corresponding shape and size. Only a few of radiography's many applications will be mentioned here, since there are several x-ray handbooks and texts which may be consulted for further details.

It would not be correct to recommend radiography as the best method for the inspection of every kind of object. It is best suited to the inspection of the first units of a new product or for control inspection of products where the failure of only one would be disastrous. It has long been used to inspect castings for flaws such as sand inclusions or porosity. It is frequently used to inspect the quality of welds in high-pressure tanks, ship hulls, structural girders, etc.

While the detection of flaws in materials is the most common application of radiography, there are many others that do more to stir the imagination. For example, it may be used to determine the location of channels in castings or of girders in a roof, without the necessity of stripping off the outer material. Radiography in the form of fluoroscopy can be used on the production line for rapid inspection of concealed assemblies, or perhaps only to see that sealed cans are properly filled. A very interesting application is the radiography of flowers and leaves. As the veins are thicker than the other parts, they leave an artistically interesting series of lines on the photographic film. Radiographing porous or veined specimens previously soaked in a heavy atom-bearing solution allows study of the diffusion rates and paths in the specimens. Paper products may sometimes be radiographed to advantage. By using a very low-voltage, such as one would use for flowers and leaves, the grains in the paper may be revealed and the quality of the paper determined. The quality of glued joints may be determined. In contrast, steel specimens many inches thick may be successfully radiographed with million-volt x-ray equipment.

A relatively new field of radiography, sometimes called microradiography, embraces radiographic studies of very small sections. In this technique very thin specimens are radiographed in a fairly conventional manner, and the resulting radiographs are then enlarged several times. The result is a radiograph that looks something like a photomicrograph but differs in that it gives information about the structure of

the sample throughout its thickness as well as over its area.

X-RAY FACILITIES AT TECH

The primary purpose of an x-ray laboratory will naturally determine the specific equipment that it should contain. Ours consists of a lead-lined room housing the equipment, darkroom facilities, and suitable office space. It is provided with a shielded operator's booth to afford adequate protection of personnel.

The x-ray equipment is composed of five x-ray machines and their accessories. Two of these machines are radiographic units, two are general purpose x-ray diffraction units, and the fifth is a crystal orientation unit designed specifically for orienting quartz crystals prior to cutting them into oscillator blanks.

One radiographic unit is of the low-voltage, portable type, suitable for radiographing relatively thin specimens of such dense materials as steel. It is particularly useful because of its portable nature and because it is designed to produce very low voltage x-rays.

The other radiographic unit is of the standard type built by Westinghouse. The voltage applied to the x-ray tube may be varied from 30 to 150 kilovolts. It is capable of radiography that requires neither a very high nor an extremely low voltage. Thus it is useful for the majority of applications.

In addition to the usual film-recording facilities for radiographs, the laboratory also contains a fluoroscopic screen that may be viewed in safety from within the operator's booth. This has proved to be an extremely useful device, since quite frequently a quick observation and no permanent record are desired. For example, small aluminum castings have been inspected for gross flaws, and shoe heels have been inspected for bent nails.

At present, the laboratory contains two x-ray diffraction units using four-port, watercooled, interchangeable, commercially available tubes. X-ray diffraction tubes for these units offer a selection of copper, iron, or molybdenum targets.

One of these units has just been acquired and put into operation. At the same time, a Geiger-counter spectrometer-goniometer with automatic recording was obtained. This device is capable of scanning the diffraction pattern of polycrystalline samples and recording, much more accurately than the photographic method, the intensity, position, breadth and shape of the diffracted lines. The cover picture is a photograph of the two x-ray diffraction units, some cylindrical powder cameras and the spectrometer-goniometer in operation in the laboratory. With the two units to furnish monochromatic x-rays and the spectrometer-goniometer and a selection of powder cameras to record the diffraction patterns, the laboratory now has facilities that are adequate to handle the majority of x-ray diffraction problems. Grain-size measurements may be made, depth of cold-work determined, strain detected, simple crystal structures determined, samples identified, quantitative analyses made, preferred orientation detected and measured, etc.

As funds permit, the facilities of the x-ray laboratory will be augmented in an effort to make it capable of the broadest possible service. Even at present it possesses equipment adequate for attack of the great majority of x-ray problems, and it is hoped that the availability of such facilities at Georgia Tech will prove of benefit to the industries of our area.

JOB STUDY

Continued from Page 10

posure by exposure, and the occurrence of the various types of activity was tallied. (See Figure 2 for an enlarged picture of a segment of the film record.) The "Idle" classification established in the preliminary investigation was not used, since idleness or lack of observable activity could not be recognized as such. It was assumed that apparent lack of action was related to mental activity involved in the discharge of duty.

The results obtained from the analysis of the individual exposures were:

Activity	*Number of Occurrences*	*Per Cent Occurrence*
Typing	258	27.2
Seated at desk	164	17.2
Standing at desk	75	7.9
At files	24	2.5
At phone	70	7.4
Talking	42	4.4
Walking	34	3.6
Gone from desk	283	29.8

These percentages approximate the true percentage of the total time devoted to the duties listed. The correctness of the approximations will depend upon how well the observations represent the true situation, which can be evaluated statistically.

Using the technique described, as many as 4,000 individual observations, taken at random or regular intervals, can be recorded on one 100-foot roll of 16-mm. motion picture film. These observations can be made automatically and without attention once the camera equipment has been set up. The main requirement for successful employment of photographic job study is that the activity to be studied is such that it can be recorded photographically and properly classified when the film record is later examined. This technique should prove to be extremely valuable as a control and evaluation aid.

ELECTRIFICATION IN AEROSOL STUDIES

Continued from Page 8

tion of the temperature of the heaters, the flow rate of the air stream or the rate of ionic nuclei production. The aerosol stream leaving the condensing section of the generator is diluted immediately with dry air and then diluted a second time just before entering a comparatively large mixing chamber. This arrangement permits the introduction of either pure air or humid air at the second dilution point, while the first dilution ensures an aerosol sufficiently dilute to be quite stable. Upon leaving the mixing chamber, the aerosol passes through a light-scattering chamber, where the intensity of light scattered by the particles (at an angle of 140° with the reversed direction of the incident light beam) is measured through a phototube circuit with an ammeter. The light scattered has been shown to be a function of the diameter and number, as well as the optical properties, of the particles. Thus the effect of introducing water vapor or any other vapor through the second dilution line can be determined from changes in the scattered light. With the conditions usually employed, changes produced by a vapor are apparent about five minutes after its introduction. Since only this short period of time is required to obtain the indication, the probability of a change in the aerosol due to causes other than the presence of the vapor is reduced to a minimum. The humidity in the mixing chamber, controlled by adjustment of flow rates of the aerosol and diluent streams, is obtained from readings on a wet- and dry-bulb thermometer unit installed in an exit line. Samples of the aerosol particles for electron microscope studies are obtained with a thermal precipitator which is connected by a tube to the mixing chamber.

Figure 1 shows that the intensity of light scattered by ammonium chloride particles in a humid atmosphere (40 per cent relative humidity) is much greater than that in a dry atmosphere. The individual particles have an average diameter of the order of 0.2 micron, and, in this size range, an increase in the mean particle diameter due to aggregation results in an increase in the intensity of the scattered light. Since there is only very little light scattered from water vapor in the absence of aerosol particles, the increase in scattered light results almost entirely from changes in the suspended particles themselves. That this increase in average diameter is a consequence of aggregation has been confirmed by electron photomicrographs. Therefore, an increase in the inten-

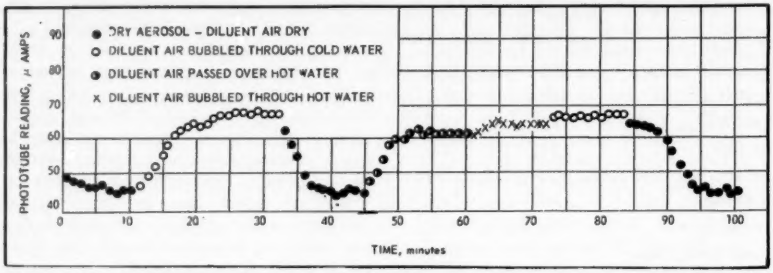

DRY AEROSOL – DILUENT AIR DRY
DILUENT AIR BUBBLED THROUGH COLD WATER
DILUENT AIR PASSED OVER HOT WATER
DILUENT AIR BUBBLED THROUGH HOT WATER
PHOTOTUBE READING, μ AMPS
TIME, minutes

Figure 2. The particle size of the aerosol (as indicated by light scattering) varied somewhat with different techniques of water introduction although the relative humidity of the moist air was the same in all cases.

sity of scattered light may be taken as a measure of the amount of aggregation.

The effect of varying the method of producing the water vapor is shown in Figure 2. It is evident that the humidity produced by bubbling air through water, possibly accompanied by electrification due to rupture of the liquid surface, results in greater aggregation than humidity produced by passing air over boiling water. The same relative humidity was maintained in both cases by regulation of the flow rates. That bubbling air through cold water causes somewhat greater light scattering than through hot water may be attributed to the decreased surface tension of water at increased temperatures and consequent decreased violence accompanying surface rupture. To substantiate this effect, an experiment was conducted in which air was bubbled through water the surface tension of which was decreased by the addition of a surface-active agent. Figure 3 shows that, after the addition of the surfactant, aggregation was diminished, as evidenced by the change in scattered light.

Since radioactive materials such as radium impart charges to the surrounding medium, a small amount of capsuled radium placed in the ammonium chloride aerosol stream would be expected to change the amount of aggregation and scattered light intensity. Figure 4 shows that the presence of radium inhibited the increase in scattered light intensity which normally accompanies the introduction of water vapor to the ammonium chloride aerosol, thus signifying reduced aggregation.

Although the above discussion has emphasized the effects on a specific aerosol by a specific vapor, many tests in this work have been concerned with other systems. Various

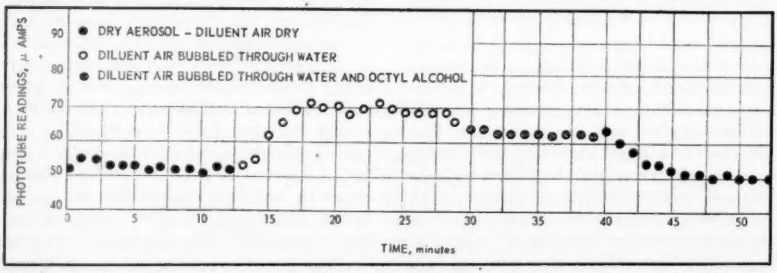

DRY AEROSOL – DILUENT AIR DRY
DILUENT AIR BUBBLED THROUGH WATER
DILUENT AIR BUBBLED THROUGH WATER AND OCTYL ALCOHOL
PHOTOTUBE READINGS, μ AMPS
TIME, minutes

Figure 3. When the surface tension of the water through which the air was bubbled was reduced by addition of octyl alcohol, the aggregating effect of humidification was decreased.

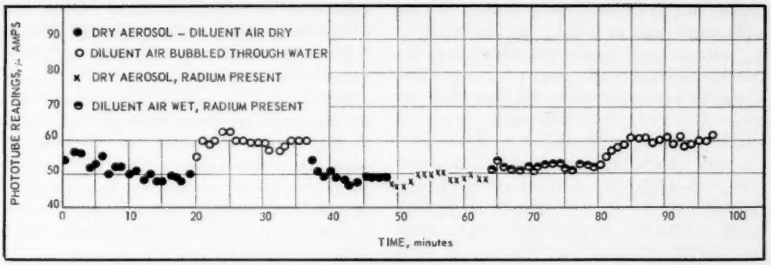


Figure 4. Electrical charges imparted by radium appear to inhibit the aerosol aggregation that normally accompanies humidification.

organic vapors, e.g., propylene, methyl and ethyl alcohol, glycerol, benzene, carbon tetrachloride and phenol, have been tested for aggregative effects on several aerosol media other than ammonium chloride, e.g., stearic acid, *B*-naphthol, glycerol and propylene glycol. No general statement on aggregative effectiveness seems possible at present because of the apparent specificity of certain vapors for certain media. Thus far, the most drastic effects have been observed on the ammonium chloride system in the presence of water vapor, propylene glycol and glycerol.

The effect of vapors on the aggregation of aerosol systems is a subject which abounds in postulated theories, assertions and refutations. In spite of the evidence presented, it is still questioned whether the observed changes in aggregation as a result of bubbling air through water, the presence of radium, etc., can be satisfactorily explained on the basis of electrical effects. Much more information concerning the chemical and physical characterization of both the discrete particles and the suspending medium must be gathered before rigorous conclusions can be drawn. It is often difficult to explain or reconcile the apparent discrepancies between the experimental results of some workers and the conclusions drawn by others. Some of the classical experiments by pioneers in the field of aerosol technology have led to statements that there are no marked differences in coagulation rates of comparable smokes which differ greatly in electrical character; that electrification exercises little, if any, effect on coagulation; that even the presence of intense x-rays does not bring about changes in the rate of aggregation of the same smoke. Many investigators have reported the effect of certain vapors on the aggregation of specific media—some of their experimental results being contradictory—and one investigator has stated that foreign vapors have no effect whatsoever and that contrary evidence is due to errors of technique. Much of the confusion arises from extrapolation of evidence on a specific aerosol system to generalizations intended to cover all aerosol systems, while many of the contradictions can be traced to different methods of investigation. To clarify the existing confusion, investigations at the Georgia Institute of Technology will include analysis of the chemical and physical nature of the discrete particles as well as the characteristics of the suspending medium. At the present time, a device to analyze the electrical nature of the discrete particles is being constructed, and it is hoped that evidence gathered in future studies, combined with the results of previous work, will permit accurate prediction of aerosol behavior and elucidation of the mechanism of aggregation.

RAW MATERIALS

Continued from Page 6

reports, the supply of prime fibers for paper making promises to remain short for some time. This is attributed partly to decreased supplies from imports and partly to in-

creased usage of long-fiber pulps. Use of grain straws and of bagasse, the latter being the residue from sugar-cane after the juice and sugar have been extracted, has been suggested to supplement the usual pine or spruce wood sources. While their use might ease supply difficulties to some extent, they are crop by-products and, as such, are seasonal and uncertain. A better answer to the problem would be a long-fiber plant that would regenerate itself several times faster than present sources. Bamboo may be such a plant, and there are varieties which produce fibers of sufficient length for paper making. Some varieties of bamboo have been investigated with promising results. Bamboo pulp has been used successfully in India for over 25 years in the manufacture of a variety of papers, including high quality book and writing paper. It is used there for Kraft paper and, mixed with mechanical pulp, is reportedly suitable for newsprint. Cellulose fibers from bamboo presumably should serve equally well in the manufacture of rayon.

About $125,000,000 worth of jute and jute products, such as burlap, rug backing, rope and other cordage products are used annually in this country. All raw jute and many of the products must be imported from halfway around the world, mainly from India. Since 1946, supplies of this fiber have been inadequate, because the jute crop in India has been deemphasized in favor of more-needed food crops. A very promising substitute for jute is under development in this country at the present time. This fiber is kenaf, which has been exploited to some extent in Java for weaving into sacks for use in the sugar industry. Kenaf fiber has been produced in India and in several other countries for local use. Areas in Florida, Texas, Indiana and New Jersey have been test-planted with kenaf, and some promising results have been obtained. For instance, in the New Jersey plantings a total yield of about 30 tons of green material per acre was produced in about 125 days. If some of the difficulties connected with domestic kenaf production (such as the problem of decortication and lack of mill facilities for processing the fiber) were overcome, this fiber source might help to reduce the nation's dependence upon foreign sources of supply.

The United States also has need for more essential-oil and drug crops. In fact, only a very small percentage of the required amounts of these materials are domestically produced. Various synthetic products have reduced our reliance upon foreign sources for some materials of these types. However, many essential oils and drugs possess properties which have never been reproduced synthetically. Among these is ergot, a fungus or mold found on rye kernels and other grains, which contains several alkaloids especially useful in the alleviation of the pain and hemorrhage of childbirth. Since ergot comes principally from Europe, efforts have been made to locate or develop sources for domestic production. Ergot could be produced by introducing the fungus into our grain fields in specific areas, but there is the dangerous possibility of not being able to control it. If it should spread to other areas, it could prove a serious setback to the diligent work of American agriculturists in reduction of crop diseases. Even if production were developed on this basis, the necessity of using hand labor for harvesting the diseased grain would be an economic problem. A more promising answer has been found in a mushroom native to Florida which contains a substance possessing ergot-like properties. If this or other domestic sources were developed, the producers could expect a potential market of some $1,000,000 per year.

Khellin, an excellent anti-hypertension agent and a drug also effective in relaxing the so-called smooth muscles of the body, is derived from the *Ammi visnaga* plant which grows in North Africa. The Egyptian government holds a monopoly on its supply which does not meet the present demand, much less the demand of new uses. Consequently, research on the use of khellin in the treatment of asthma and other pulmonary diseases has been restricted.

Oil of coriander is one of several essential oils which are needed and can be grown

domestically. This material, which is used principally in the food, tobacco and beverage industries, is produced largely in Russia. Consequently, the material received in this country is usually purchased through other countries, such as Argentina, at exorbitant prices.

The cultivation of essential oil and drug plants in this country could do much to remedy conditions exemplified by ergot, khellin and oil of coriander. Production of such crops should prove profitable to the grower, since it has been estimated that the return per acre would be about six times that of other established crops.

The control of insect pests by the use of proper insecticides has permitted the United States farmer to produce more crops per acre. Research by American scientists has resulted in the development of many useful synthetic insecticides. However, there are several valuable insecticides derived from botanical sources for which no entirely satisfactory synthetic substitutes have been developed. Among these are ryania, sabadilla and pyrethrum. Ryania is used to control the corn borer, and sabadilla is the only thing found to date which will effectively control the "stink bug" or "pumpkin bug." Pyrethrum is the standard agent for "quick knockdown" household insecticides. It also finds widespread use as a finishing insecticide in the agricultural field. Most of the presently available pyrethrum flowers are produced in the British Kenya Colony in Africa, but there have not been enough grown in recent years to satisfy the growing world demand. In addition, United States needs are considered only after Britain's own demands are filled. The cultivation of pyrethrum flowers has been revived in some areas. However, the material is not finding its way into United States markets, since the producers prefer to sell the flowers on the basis of their own pyrethrins analysis with no rebate if the material is of lower quality when checked on arrival in this country. It is understandable that few American concerns care to bargain under such conditions. A relatively new synthetic insecticide, known as allethrin, has been shown to serve as a substitute for pyrethrum in some uses. However, about the only advantage allethrin has over pyrethrum at the present time is its availability. This situation might be changed if the present shortage of pyrethrum, which will grow in the United States, were relieved by domestic production.

The use of a so-called synergist in an insecticide permits the use of lower concentration of the active ingredient and results in greater killing power. Sesamine, one of the synergists used for pyrethrum, is derived from sesame oil. At the present time the price that must be paid for sesamine-containing extractives is high. Domestic production of sesame oil and pyrethrum should result in lower-cost insecticides.

Sesame oil shows great promise as a new addition to the domestic supply of edible oils. In addition, sesame seeds contain a high-protein residue after removal of the oil, an essential requirement of economically feasible oil seed crops. Thus, sesame is a plant which could prove most valuable to the country's economy both in peace and in war. Sesame oil possesses some properties which make it desirable both to industry and to individual consumers of oils. It has a long storage or shelf life since it does not become rancid rapidly, and the hydrogenated form possesses a very high stability. The processors of vegetable oils will find the seeds easy to process in conventional mills and the oil easy to refine. The sesame plant, which has been grown for food in Asia and Europe since ancient times and can be grown in the United States, produces about twice as much oil per acre as our present oil crops. Sesame should be of particular interest to cotton-producing states, since it shows great promise as an answer to the need for protein and oil crops as a supplement to cotton. Protein crops for animal feed are highly essential to bring about balanced farming in these areas. Such balance is necessary to insure a more even income and proper use of the land. Some problems of adapting the plant to large-scale farming methods are now under study. When they have been solved, sesame may well become a valuable addition to domestic oil-producing crops.

While the items which have been dis-

creased usage of long-fiber pulps. Use of grain straws and of bagasse, the latter being the residue from sugar-cane after the juice and sugar have been extracted, has been suggested to supplement the usual pine or spruce wood sources. While their use might ease supply difficulties to some extent, they are crop by-products and, as such, are seasonal and uncertain. A better answer to the problem would be a long-fiber plant that would regenerate itself several times faster than present sources. Bamboo may be such a plant, and there are varieties which produce fibers of sufficient length for paper making. Some varieties of bamboo have been investigated with promising results. Bamboo pulp has been used successfully in India for over 25 years in the manufacture of a variety of papers, including high quality book and writing paper. It is used there for Kraft paper and, mixed with mechanical pulp, is reportedly suitable for newsprint. Cellulose fibers from bamboo presumably should serve equally well in the manufacture of rayon.

About $125,000,000 worth of jute and jute products, such as burlap, rug backing, rope and other cordage products are used annually in this country. All raw jute and many of the products must be imported from halfway around the world, mainly from India. Since 1946, supplies of this fiber have been inadequate, because the jute crop in India has been deemphasized in favor of more-needed food crops. A very promising substitute for jute is under development in this country at the present time. This fiber is kenaf, which has been exploited to some extent in Java for weaving into sacks for use in the sugar industry. Kenaf fiber has been produced in India and in several other countries for local use. Areas in Florida, Texas, Indiana and New Jersey have been test-planted with kenaf, and some promising results have been obtained. For instance, in the New Jersey plantings a total yield of about 30 tons of green material per acre was produced in about 125 days. If some of the difficulties connected with domestic kenaf production (such as the problem of decortication and lack of mill facilities for processing the fiber) were overcome, this fiber source might help to reduce the nation's dependence upon foreign sources of supply.

The United States also has need for more essential-oil and drug crops. In fact, only a very small percentage of the required amounts of these materials are domestically produced. Various synthetic products have reduced our reliance upon foreign sources for some materials of these types. However, many essential oils and drugs possess properties which have never been reproduced synthetically. Among these is ergot, a fungus or mold found on rye kernels and other grains, which contains several alkaloids especially useful in the alleviation of the pain and hemorrhage of childbirth. Since ergot comes principally from Europe, efforts have been made to locate or develop sources for domestic production. Ergot could be produced by introducing the fungus into our grain fields in specific areas, but there is the dangerous possibility of not being able to control it. If it should spread to other areas, it could prove a serious setback to the diligent work of American agriculturists in reduction of crop diseases. Even if production were developed on this basis, the necessity of using hand labor for harvesting the diseased grain would be an economic problem. A more promising answer has been found in a mushroom native to Florida which contains a substance possessing ergot-like properties. If this or other domestic sources were developed, the producers could expect a potential market of some $1,000,000 per year.

Khellin, an excellent anti-hypertension agent and a drug also effective in relaxing the so-called smooth muscles of the body, is derived from the *Ammi visnaga* plant which grows in North Africa. The Egyptian government holds a monopoly on its supply which does not meet the present demand, much less the demand of new uses. Consequently, research on the use of khellin in the treatment of asthma and other pulmonary diseases has been restricted.

Oil of coriander is one of several essential oils which are needed and can be grown

domestically. This material, which is used principally in the food, tobacco and beverage industries, is produced largely in Russia. Consequently, the material received in this country is usually purchased through other countries, such as Argentina, at exorbitant prices.

The cultivation of essential oil and drug plants in this country could do much to remedy conditions exemplified by ergot, khellin and oil of coriander. Production of such crops should prove profitable to the grower, since it has been estimated that the return per acre would be about six times that of other established crops.

The control of insect pests by the use of proper insecticides has permitted the United States farmer to produce more crops per acre. Research by American scientists has resulted in the development of many useful synthetic insecticides. However, there are several valuable insecticides derived from botanical sources for which no entirely satisfactory synthetic substitutes have been developed. Among these are ryania, sabadilla and pyrethrum. Ryania is used to control the corn borer, and sabadilla is the only thing found to date which will effectively control the "stink bug" or "pumpkin bug." Pyrethrum is the standard agent for "quick knockdown" household insecticides. It also finds widespread use as a finishing insecticide in the agricultural field. Most of the presently available pyrethrum flowers are produced in the British Kenya Colony in Africa, but there have not been enough grown in recent years to satisfy the growing world demand. In addition, United States needs are considered only after Britain's own demands are filled. The cultivation of pyrethrum flowers has been revived in some areas. However, the material is not finding its way into United States markets, since the producers prefer to sell the flowers on the basis of their own pyrethrins analysis with no rebate if the material is of lower quality when checked on arrival in this country. It is understandable that few American concerns care to bargain under such conditions. A relatively new synthetic insecticide, known as allethrin, has been shown to serve as a substitute for pyrethrum in some uses. However, about the only advantage allethrin has over pyrethrum at the present time is its availability. This situation might be changed if the present shortage of pyrethrum, which will grow in the United States, were relieved by domestic production.

The use of a so-called synergist in an insecticide permits the use of lower concentration of the active ingredient and results in greater killing power. Sesamine, one of the synergists used for pyrethrum, is derived from sesame oil. At the present time the price that must be paid for sesamine-containing extractives is high. Domestic production of sesame oil and pyrethrum should result in lower-cost insecticides.

Sesame oil shows great promise as a new addition to the domestic supply of edible oils. In addition, sesame seeds contain a high-protein residue after removal of the oil, an essential requirement of economically feasible oil seed crops. Thus, sesame is a plant which could prove most valuable to the country's economy both in peace and in war. Sesame oil possesses some properties which make it desirable both to industry and to individual consumers of oils. It has a long storage or shelf life since it does not become rancid rapidly, and the hydrogenated form possesses a very high stability. The processors of vegetable oils will find the seeds easy to process in conventional mills and the oil easy to refine. The sesame plant, which has been grown for food in Asia and Europe since ancient times and can be grown in the United States, produces about twice as much oil per acre as our present oil crops. Sesame should be of particular interest to cotton-producing states, since it shows great promise as an answer to the need for protein and oil crops as a supplement to cotton. Protein crops for animal feed are highly essential to bring about balanced farming in these areas. Such balance is necessary to insure a more even income and proper use of the land. Some problems of adapting the plant to large-scale farming methods are now under study. When they have been solved, sesame may well become a valuable addition to domestic oil-producing crops.

While the items which have been dis-

cussed are only representative of the numerous needs that were disclosed by the survey, they have been cited to exemplify the various problems connected with raw material procurement. Some of the possible solutions to these problems have been pointed out for these specific commodities, but each raw material problem of this sort requires individual investigation. Some of the items uncovered by the survey apparently have enough economic and practical value to industry and the farmer to warrant more detailed study. Consequently, the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, has decided to continue the program through 1952, if possible. Its program will include a detailed study of what is now known concerning the life history and cultivation of certain potential crops, as well as the processing of specific raw materials. Industrial applications and the past, present and future economic possibilities will also be considered. The detailed information obtained should definitely indicate those plants that should be introduced into this country. In this way the survey will aid in providing the American farmer with more profitable and diversified crops. It will also assist industry in the development of a more reliable supply of needed raw materials. In doing these two things, the survey should be a real help in providing the United States with a stronger, more stable domestic economy.

APPRECIATION OF RESEARCH

Continued from Page 2

ica of new ideas and concepts in that field. After all, we must acknowledge our huge debt to Europe for much of the pure science background upon which we have built our present technological superiority. We needed chemical engineers to get where we are—to develop the processes and design the plants which are the bulwarks of our peacetime economy and our wartime strength. Europe needs them now; and, quite apart from any anticipated scientific benefits, we stand to gain materially, both in trade and in defense savings, by helping the free nations train men to do for them what their American counterparts have done for us.

However, a strong chemical engineering profession is not our foreign allies' sole need. They must be able to bridge the gap between their excellent basic research and the plants that could utilize the concepts it brings to light. To help them do this, the National Research Council has prepared a booklet entitled "Applied Research in the United States." Its editor says that American industrialists, accustomed to utilizing the basic research data developed in universities and elsewhere, will find much of the material quite familiar. However, he continues, Europeans, unaccustomed to handling applied research and development on the American scale and without a working relationship for the exchange of ideas with universities, should find the booklet informative.

Western European industrialists have long been handicapped by two important factors: lack of competent chemical engineers and lack of sufficient applied research to translate concepts to reality. We hope both deficiencies will soon be remedied. However, we believe that some of our own industries, and certainly many companies in them, have failed to make full use of the engineering talent and research facilities available to them. We wonder how many company executives would find the National Research Council's booklet quite *unfamiliar* to them. We also wonder how many of them, after studying the booklet, would decide that a working relationship with the universities to obtain basic research data and use of our nation's nonprofit research institutes to translate these data into practical applications are opportunities they can no longer afford to ignore.